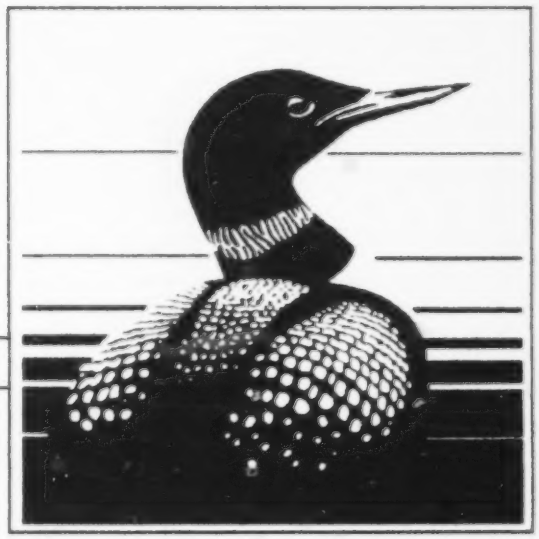
Abundance and distribution of Common Murres breeding at Funk Island, Newfoundland in 1972 and 2000

John W. Chardine, Gregory J. Robertson, Pierre C. Ryan, and Bruce Turner

Atlantic Region 2003
Canadian Wildlife Service
Environmental Conservation Branch



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ABUNDANCE AND DISTRIBUTION OF COMMON MURRES BREEDING AT FUNK ISLAND, NEWFOUNDLAND IN 1972 AND 2000

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Canadian Wildlife Service Technical Report No. 404

This report may be cited as:

Chardine, J.W., G.J. Robertson, P.C. Ryan and B. Turner. 2003. Abundance and distribution of Common Murres breeding at Funk Island, Newfoundland in 1972 and 2000. Technical Report Series No. 404. Canadian Wildlife Service, Atlantic Region. iv. + 15 pp.

Published by authority of the
Minister of Environment
Canadian Wildlife Service

©Minister of Supply and Services Canada 2003
Catalogue No.: CW69-5/404E
ISBN: 0-662-34431-6

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Abstract

The area and size (number of pairs) of the Common Murre colony on Funk Island, Newfoundland were estimated from aerial photographs taken on 19 June 1972 and 15 July 2000. The overall colony structure has remained roughly the same between years with birds breeding in three subcolonies along the central spine of the island: Southwest, Central and Indian Gulch. However, changes in distribution were apparent between the two years with murre breeding areas shrinking around the expanding Northern Gannet colony in Southwest, and increasing in the southern portion of Southwest, at the east end of Central, and in Indian Gulch. Overall, we estimate that 412,524 (95% confidence interval [CI] = 373,427 - 451,621) pairs of Common Murres bred on Funk Island in 2000 compared to 389,097 (95% CI = 372,857 - 405,337) pairs in 1972. The 2000 estimate was 6% higher than 1972 and represented an annual increase of just 0.2%. The similarity of the two estimates separated by 28 years suggests that colony size is being regulated, perhaps by availability of suitable habitat or food availability, and is surprising considering the changes that have occurred in the Newfoundland marine ecosystem between 1972 and 2000.

Résumé

Les dimensions et la taille (nombre de paires) d'une colonie de Marmettes de Troïl sur l'Île Funk, Terre-Neuve, furent estimés à partir de photographies aériennes prises le 19 juin 1972 et le 15 juillet 2000. La structure générale de la colonie est demeuré relativement similaire entre 1972 et 2000, avec des oiseaux nichant dans trois sous-colonies le long de l'axe centrale de l'île: Southwest, Central, et Indian Gulch. Cependant, des changements sont apparents au niveau de la distribution des sous-colonies. L'étendue des sites de nidification des marmettes à diminué près de la colonie de Fous de Bassan en expansion dans la colonie Southwest, et s'est agrandie dans la portion sud de Southwest, dans la portion est de Central, et dans Indian Gulch. Nous estimons que 412,524 (Intervalle de Confiance [IC] 95% = 373,427 – 451,621) paires de Marmettes de Troïl ont nichés sur l'Île Funk en 2000, comparé à 389,097 (IC 95% = 372,857 – 405,337) paires en 1972. L'estimation de 2000 est 6% plus grand que celle de 1972, et représente une croissance annuelle de seulement 0.2%. La similitude entre ces deux estimations séparés par 28 ans suggère que la taille de la colonie est contrôlée, peut-être par la disponibilité d'habitat adéquat, ou par la disponibilité de ressources alimentaires. Cette similitude est surprenante considérant les changements qui ont eu lieu dans les écosystèmes marins de Terre-Neuve entre 1972 et 2000.

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Introduction

Funk Island (49° 45' N, 53° 11' W) is a small granite outcrop located 60 km northeast of Cape Freels, northeast Newfoundland (Montevecchi and Tuck 1987). This island is home to the largest breeding colony of Common Murres, *Uria aalge*, in the western North Atlantic (Montevecchi and Tuck 1987). At Funk Island, along with many other colonies in the western North Atlantic, numbers of breeding murres were severely reduced at the turn of the century (Nettleship and Evans 1985, Montevecchi and Tuck 1987). Estimates for the 1930s and 1940s on Funk Island range between 10,000 and 15,000 breeding pairs (Tuck 1961, Montevecchi and Tuck 1987). The situation changed dramatically in the 1950s, when Tuck (1961) documented a huge increase from 50,000 breeding pairs in 1951 to 500,000 breeding pairs in 1959. If this increase were real, it represented an annual increase of about 33%, which was clearly beyond the demographic capacity of the local population; immigration from outlying areas must have occurred, although from where these birds moved is unclear. In 1972, Birkhead and Nettleship (1980) estimated 396,000 breeding pairs by measuring the area occupied by breeding murres from an aerial photograph and combining this information with known densities of birds from ground surveys.

In this paper, we present a colony size estimate for Common Murres breeding at Funk Island in 2000 and a reassessment of the 1972 photograph. We used similar techniques as Birkhead and Nettleship (1980). We also present comparable photographs from the two years side-by-side which clearly show where changes in distribution have occurred. We discuss some potential sources of error and bias in population size estimates obtained from measuring colony area from aerial photographs.

Methods

1. Flights and photography

We conducted the aerial photographic survey of Funk Island on 15 July 2000, between 1120 and 1203 NDT. The survey was conducted in a single-engine Beaver aircraft (owned and operated by Gene Ploughman of Thorburn Aviation, Thorburn Lake, NL., tel. 709-466-7823) and photographs were taken as vertically as possible (by JWC) through a hole in the belly of the aircraft, at 1000' and at an air speed of 70 knots. The pilot took care to maintain the same altitude throughout the pass over the island. We also obtained a photograph of the whole island from an altitude of 4000'. We used a Pentax 645 camera with a 75 mm lens, and Kodak TMAX 100 black and white film exposed at 1/500 sec at F 5.6. Conditions were bright and sunny with light breezes during the survey.

The film was processed and scanned to Kodak Pro Photo CD, and the highest resolution scans (4096 x 6144 pixels per inch) printed on Epson photo quality glossy paper on an Epson Color Stylus 3000 printer at a size of 12" x 16", and resolution of over 300 dpi. Six images were needed to capture the entire Funk Island Common Murre colony.

2. Photograph analysis

The Common Murre colony at Funk Island is divided into three subcolonies, named Southwest, Central and Indian Gulch (Birkhead and Nettleship 1980; Fig 1.). Two photographs covered each subcolony so we had to match adjoining images before tracing the perimeter of the colony. Each adjoining image matched up almost perfectly because the vertical angles of each image were similar. We traced the outline of the murre colony with a fine-point, permanent marker on a sheet of clear mylar laid over the photographs. The perimeter of the colony was readily determined on the images because breeding murres are densely packed on Funk Island (ca. 20-25 pairs/m^2; Birkhead and

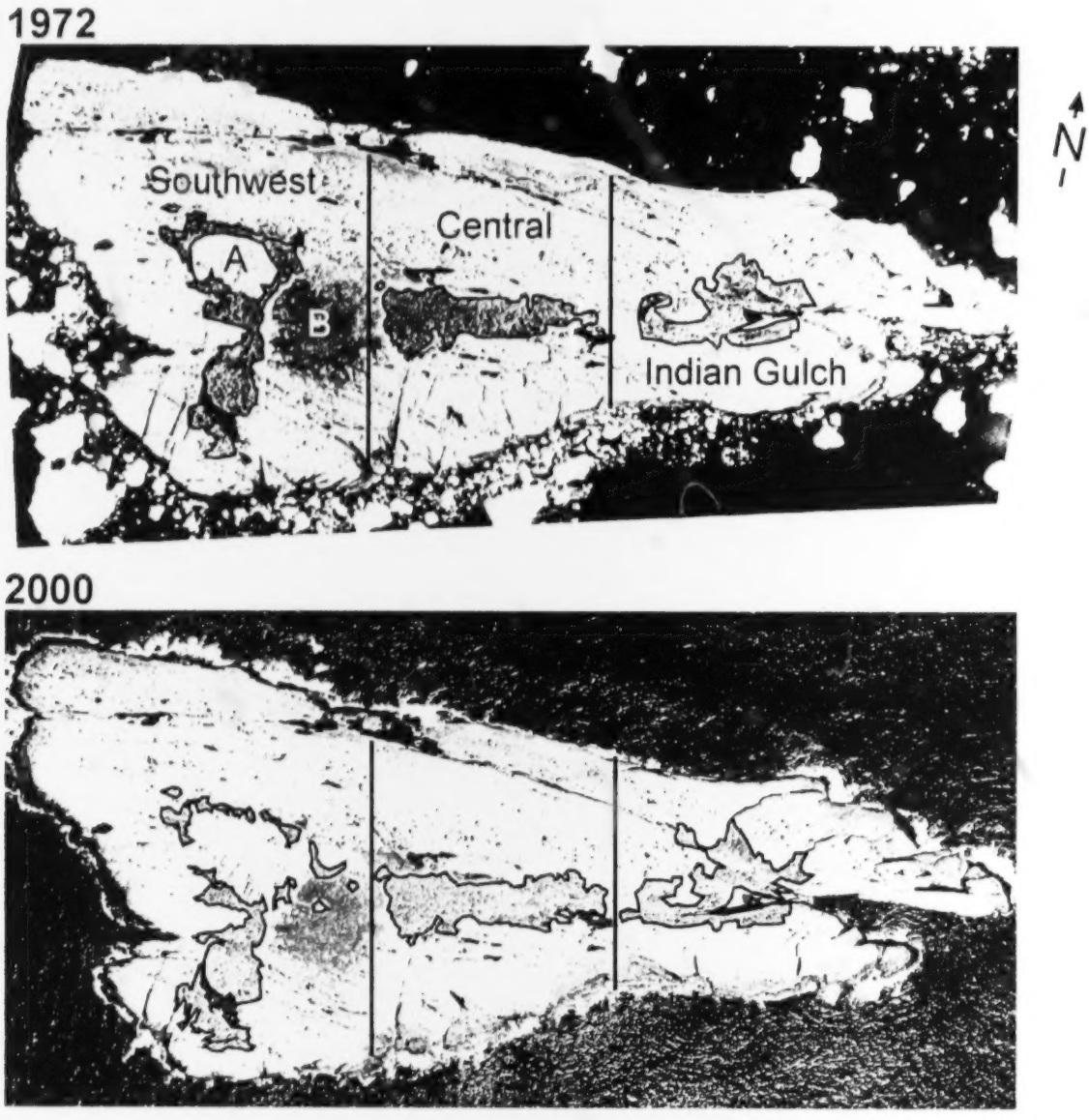

Figure 1. Images of Funk Island taken on 19 June 1972 and 15 July 2000. For comparative purposes, images were scaled and rotated using Adobe Photoshop so that they would appear similar. "A" is the Northern Gannet colony and "B" is the Atlantic Puffin colony in the turf area. The Common Murre subcolonies are indicated and outlined.

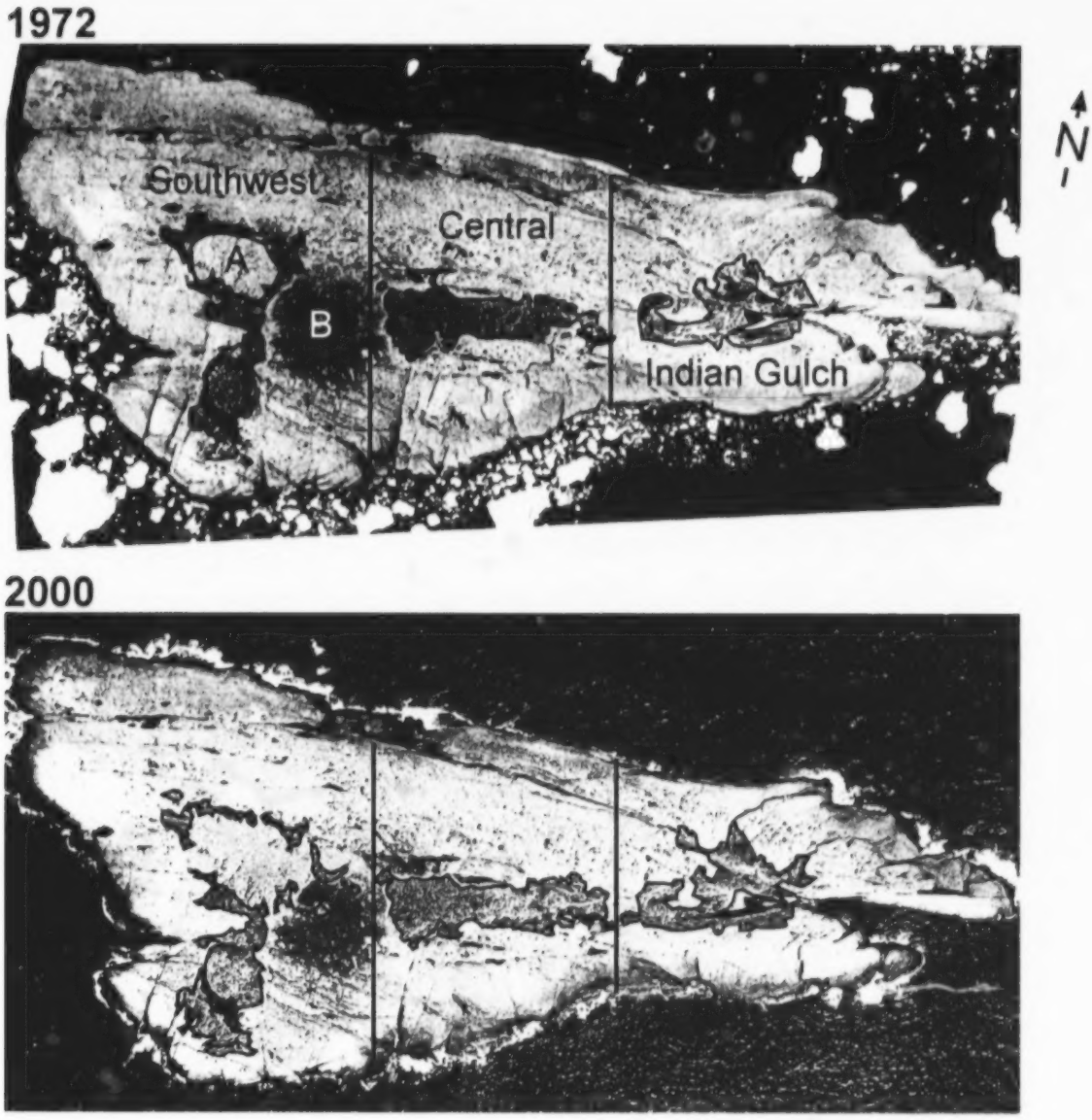

Figure 1. Images of Funk Island taken on 19 June 1972 and 15 July 2000. For comparative purposes, images were scaled and rotated using Adobe Photoshop so that they would appear similar. "A" is the Northern Gannet colony and "B" is the Atlantic Puffin colony in the turf area. The Common Murre subcolonies are indicated and outlined.

Nettleship 1980) and showed up as black, speckled regions on the photographs. In fact, individual murres were almost resolvable in these densely packed breeding areas, and were readily so in the "halo" of less densely packed birds (presumably off-duty and non-breeders) around the perimeter of the breeding areas (see Fig. 2).

The area of each subcolony was measured on the mylar tracings with a Koizumi Placom digital planimeter (model KP-90). We found the linear scale of the images by determining the distance in millimeters between features on the photographs for which we had measurements in meters on the ground (provided by W.A. Montevecchi and in Birkhead and Nettleship 1980; Table 1 and Fig. 3). Linear scales varied from 1:540 to 1:634 because of variation in the extent to which the features were photographed vertically (distance from the nadir), and because of measurement error. Therefore we used a mean linear scale of 1:575 based on seven available scale determinations across the island (Table 1). Each subcolony was measured four times and the means of these areas were reported. Areas on the photograph were multiplied by the mean linear scale^2 ($575^2 = 330{,}625$) to obtain estimates of area on the ground. The measurements for each portion of the sub-colony were summed to calculate a total sub-colony area. Subcolony areas were multiplied by breeding density figures provided by Birkhead and Nettleship (1980) to obtain an estimate of the number of breeding pairs (colony size) for each subcolony, and then summed for the whole colony.

Variance in colony area and colony size estimates were derived from variance across the four planimeter measurements and the error associated with photo scale (Table 1). The standard errors of the subcolony area estimates were calculated as follows:

$$SE_{\text{subcolony area}} = \sqrt{\frac{Var_{area}Var_{scale}}{mn} + area^2\frac{Var_{scale}}{n} + scale^2\frac{Var_{area}}{m}}, \qquad (1)$$

where, scale = 330,625, area is mean area of the subcolony on the photograph across the four planimeter measurements, m = number of planimeter measurements (4), n = number of scale measurements (7), and Var = variance. The formula follows the rule of the variance of a product and was derived by Brian Collins (pers. comm.). The standard error of the total colony area estimate was obtained as follows:

$$SE_{\text{total colony area}} = \sqrt{SE_{SW}^2 + SE_C^2 + SE_{IG}^2}, \qquad (2)$$

where SE = the individual standard errors for each subcolony area estimate in equation 1 above (SW = Southwest, C = Central, IG = Indian Gulch,). The formula follows the rule of the variance of a sum. The standard error of the subcolony size estimates were obtained as follows:

$$SE_{\text{subcolony size}} = \sqrt{d^2 SE^2_{\text{subcolony area}}}, \qquad (3)$$

where d = density of breeding pairs for each subcolony, and of the total colony size estimate as follows:

$$SE_{\text{total colony size}} = \sqrt{SE_{SW}^2 + SE_C^2 + SE_{IG}^2}, \qquad (4)$$

where SE = the individual standard errors for each subcolony size estimate in equation 3 above. To calculate confidence intervals, a conservative approach was taken in determining degrees of freedom in which the smaller of m and n was used (Brian Collins, pers. comm.).

We had access to the original photograph of Funk Island taken at 1730-1815 NDT on 19 June 1972 and the colony tracing that was used to determine area. The single photograph was taken at

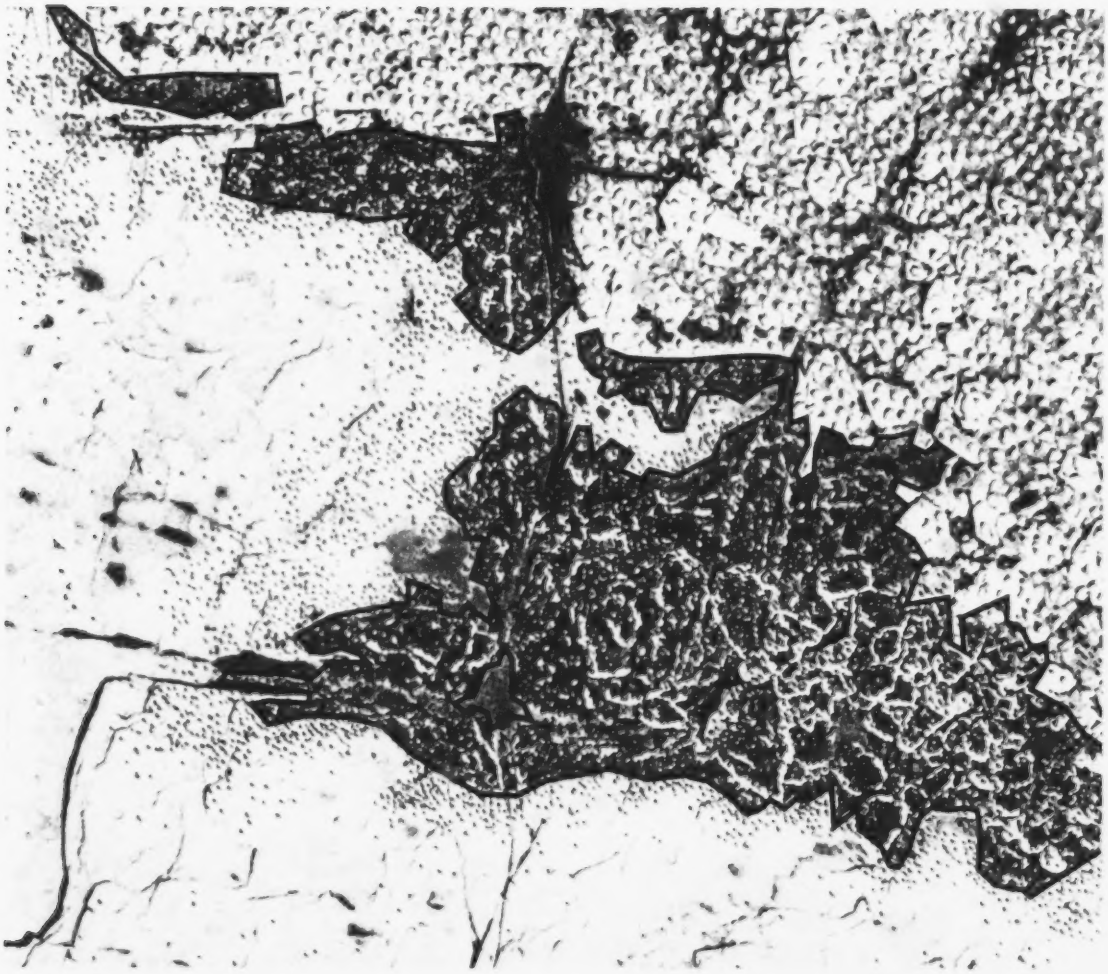

Figure 2. Close-up of a portion of the Southwest subcolony showing the breeding murres in the dark areas and the "halo" of dispersed murres around the periphery of the colony. The lines provide an example of how the colony was delineated for the purposes of determining colony area.

Table 1. Measurements between features on Funk Island used to determine photographic scale on the images from 2000. The letters refer to each measurement shown in Figure 3.

Measurement	Length on 2000 photograph (mm)	Distance on ground (m)	Scale[1]
a	54.6	29.5	1:540
b	49.0	28.5	1:581
c	37.7	21	1:557
d	33.4	19	1:569
e[2]	162	100	1:634
f	25.3	13.5	1:533
g	42.6	27	1:617
Mean			1:575
SE			14.3

1. Only measurements a, f, and g could be discerned in the 1972 photograph. They provided scales of 1:1017, 1:1063 and 1:1120 and a mean of 1:1067 (SE = 29.8).

2. Taken from 100m scale in Figure 4 of Birkhead and Nettleship (1980); balance of measurements provided by W.A. Montevecchi in 2000

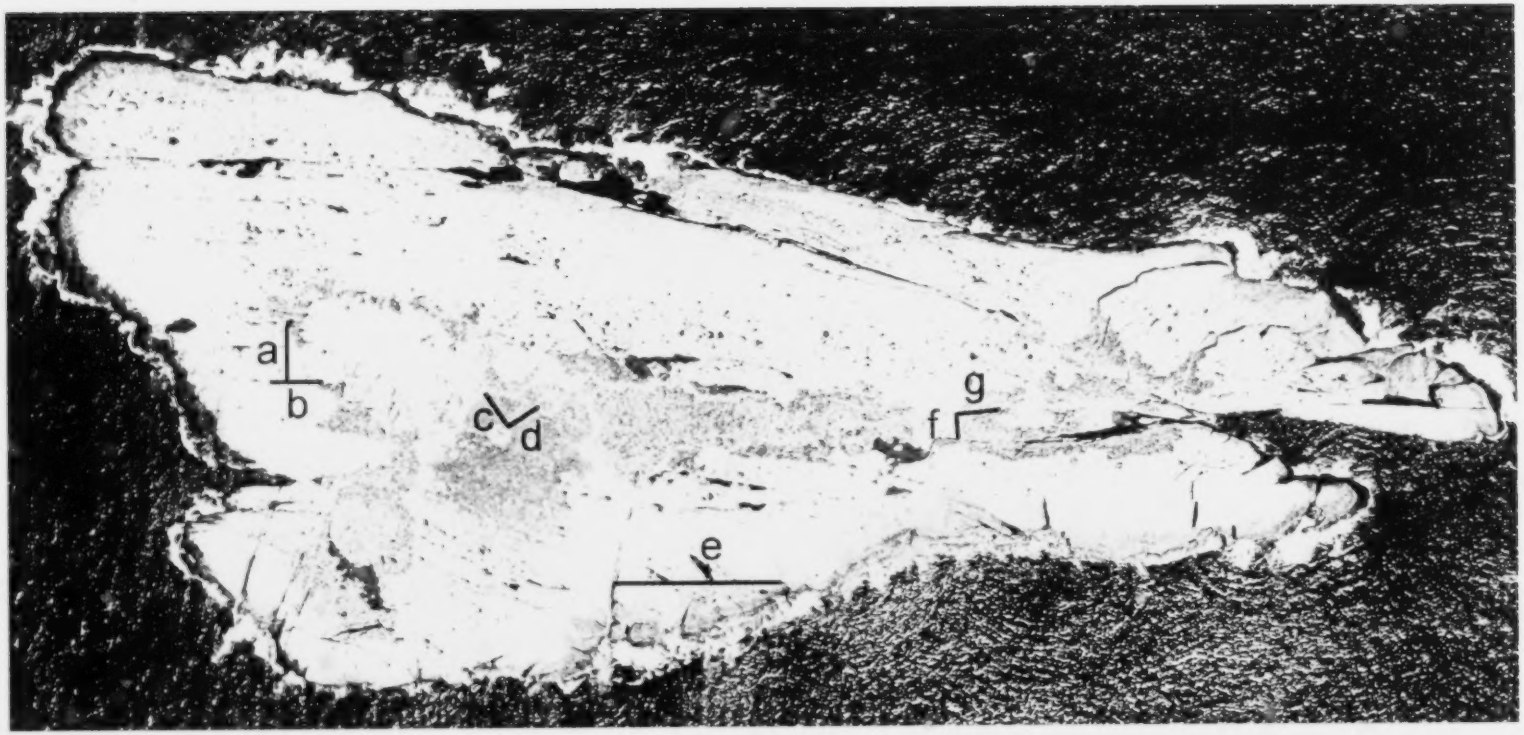

Figure 3. Aerial image of Funk Island taken in 2000 showing lengths from which scale was determined. Letters refer to lengths in Table 1.

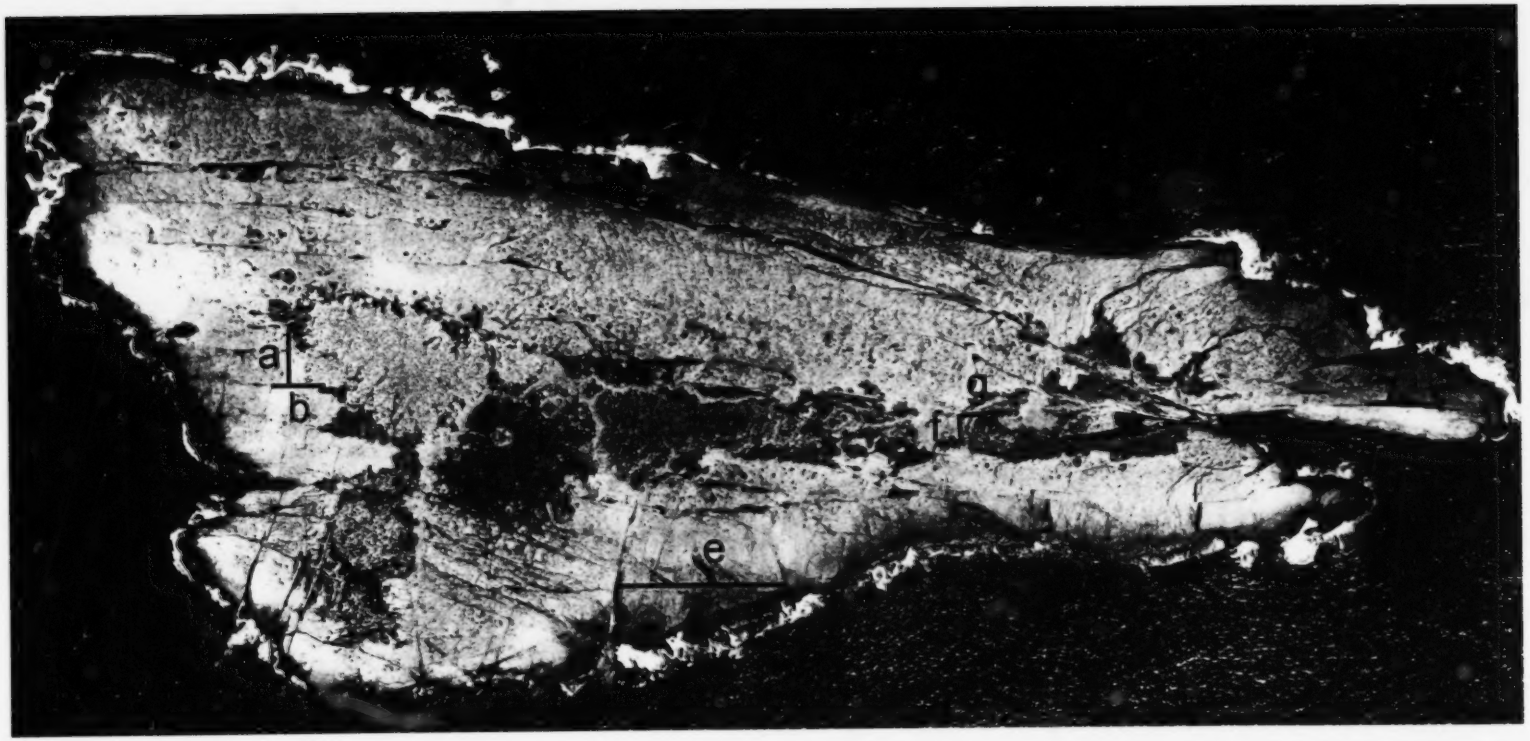

Figure 3. Aerial image of Funk Island taken in 2000 showing lengths from which scale was determined. Letters refer to lengths in Table 1.

an altitude of 4000' with a K-24 large format camera on Kodak Tri-X Aerographic film (ASA 320). The 5" x 5" negative was enlarged to 33" x 29". The mean linear scale of the 1972 photograph was 1:1067 (see Table 1 and Fig. 3). As a check on estimates already published (Birkhead and Nettleship 1980), we repeated the area calculations using the same methods as described above. Methods of calculating standard errors for the 1972 estimates were the same as for 2000.

There is a small colony of approximately 250 pairs of Thick-billed Murres, *Uria lomvia*, nesting in Indian Gulch (Montevecchi and Tuck 1987), however, we could not discriminate between Common and Thick-billed Murres in the aerial photographs.

Results

Figure 1 shows Funk Island as it appeared in 1972 (19 June, Birkhead and Nettleship) and 2000. It is clear that although the extent of the murre colony has changed over the 28 years, the integrity of the three subcolonies, Southwest, Central, and Indian Gulch, has remained. Figures 4, 5 and 6 show a close-up of each subcolony as they appeared in 1972 and 2000, with arrows indicating the major changes in the distribution of breeding murres (north is approximately towards the top of each image). The Southwest subcolony (Fig. 4) changed substantially with reductions in breeding area around the Northern Gannet (*Morus bassanus*) colony and increases to the south. The Northern Gannet colony increased from 4,051 to 9,837 pairs from 1972 to 1999 (Chardine 2000). The Central subcolony (Fig. 5) expanded between 1972 and 2000 mainly at the east end. The Indian Gulch subcolony (Fig. 6) expanded considerably between 1972 and 2000, mainly in the northern and western sections.

Table 2 shows the area and colony size estimates for 1972 and 2000. The data support the visual impressions seen in Figures 4,5 and 6: the Southwest colony area and colony size declined by 9%, and the Central and Indian Gulch subcolonies increased by 10% and 26% respectively. Note that the area estimates for 1972 that we produced were similar to those reported in Birkhead and Nettleship (1980; Table 2) except for the Central subcolony, which we estimated to be about 570 m^2 smaller. This difference amounted to about 14,000 fewer pairs. If the 1972 Central subcolony area estimate of Birkhead and Nettleship is used, there was virtually no change in the area in 2000, which is not consistent with a visual comparison provided in Figure 5.

Our estimate of the number pairs of Common Murres nesting on Funk Island in 2000 was 412,524 (95% CI: 373,427 - 451,621; Table 2). This was 6% higher than our 1972 estimate and represents an annual increase of just 0.2% ($\lambda = 1.002$).

Discussion

There is a variety of sources of error that is incorporated into estimates of colony size from area occupied in photographs. One of the more important of these is in calculating the scale of the photographs. Small errors in the measured area on the photograph can have large effects on the estimated area because of the multiplying effect of the scale and the fact that final area is related to the square of scale. Further, scale of the photographs may be different if the altitude of the plane changes during the pass. Within photographs the scale changes away from the nadir, or the point directly below the camera lens, and the scale is affected if the camera is not held perfectly level. In this study we determined the scale of the photographs using the Funk Island image published in Birkhead and Nettleship (1980) and distances between features measured on the ground. The scale

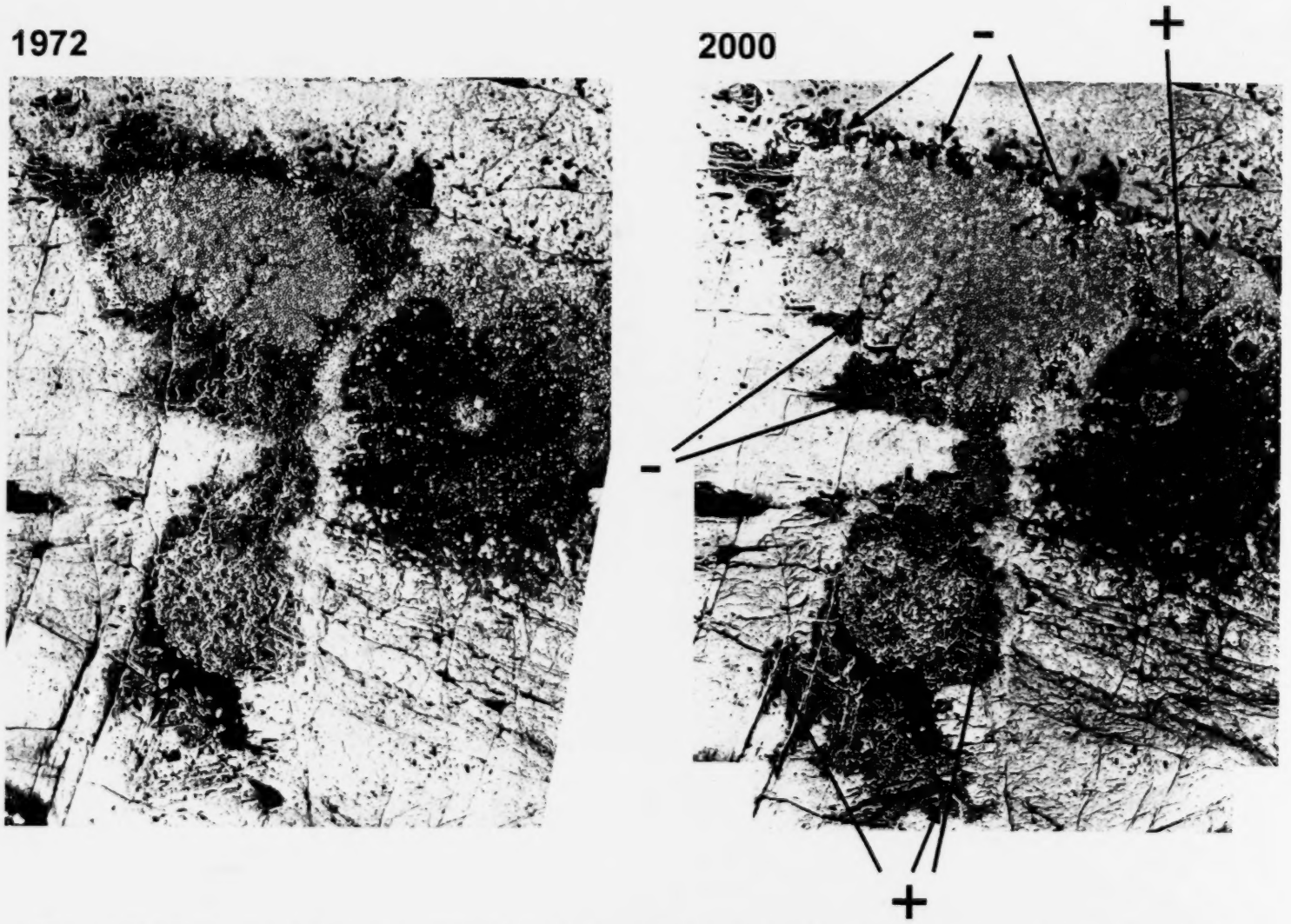

Figure 4. The Southwest subcolony as it appeared on 19 June 1972 and 15 July 2000. Areas where murres have increased (+) and decreased (-) are indicated.

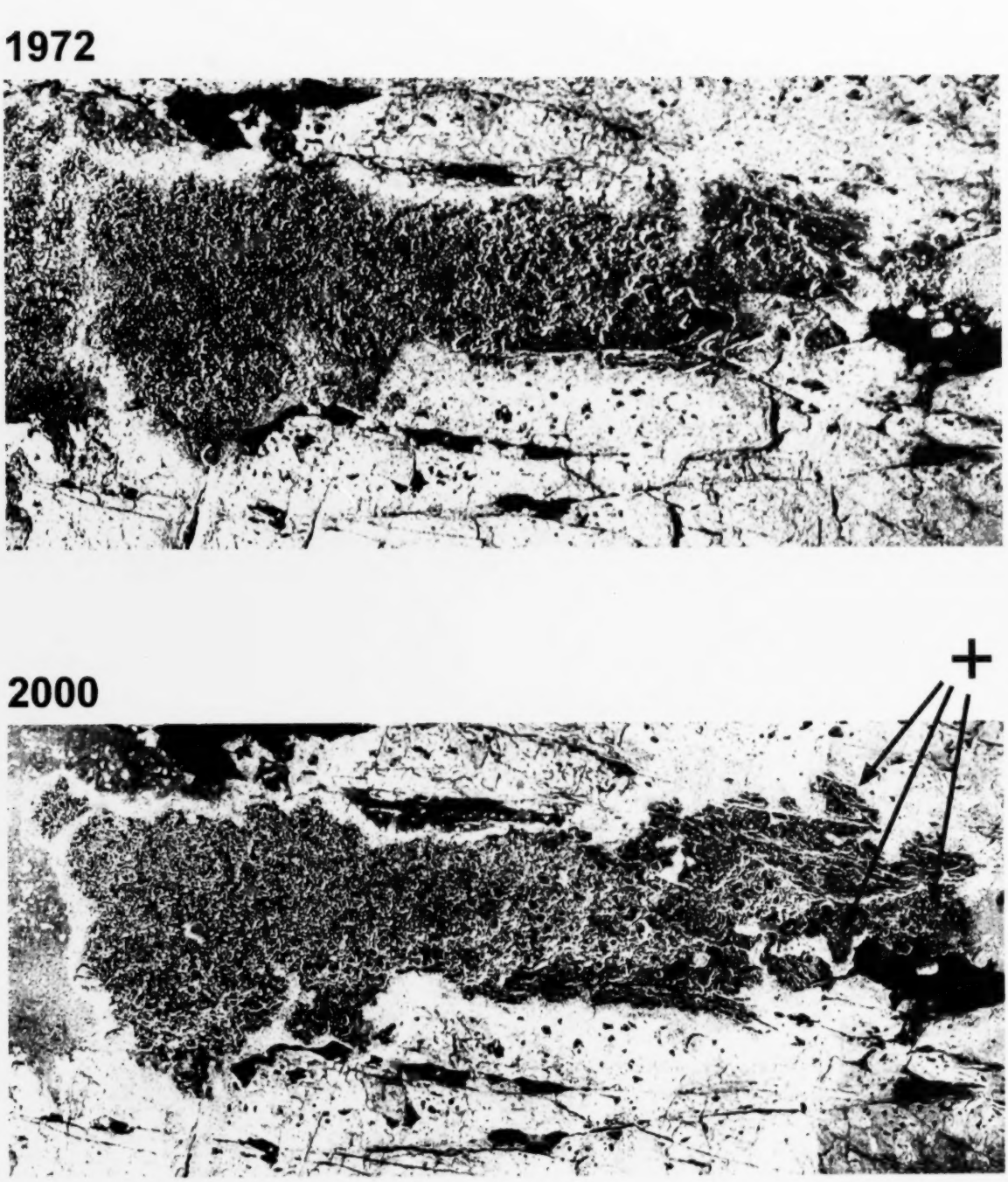

Figure 5. The Central subcolony as it appeared on 19 June 1972 and 15 July 2000. Areas where murres have increased (+) and decreased (-) are indicated.

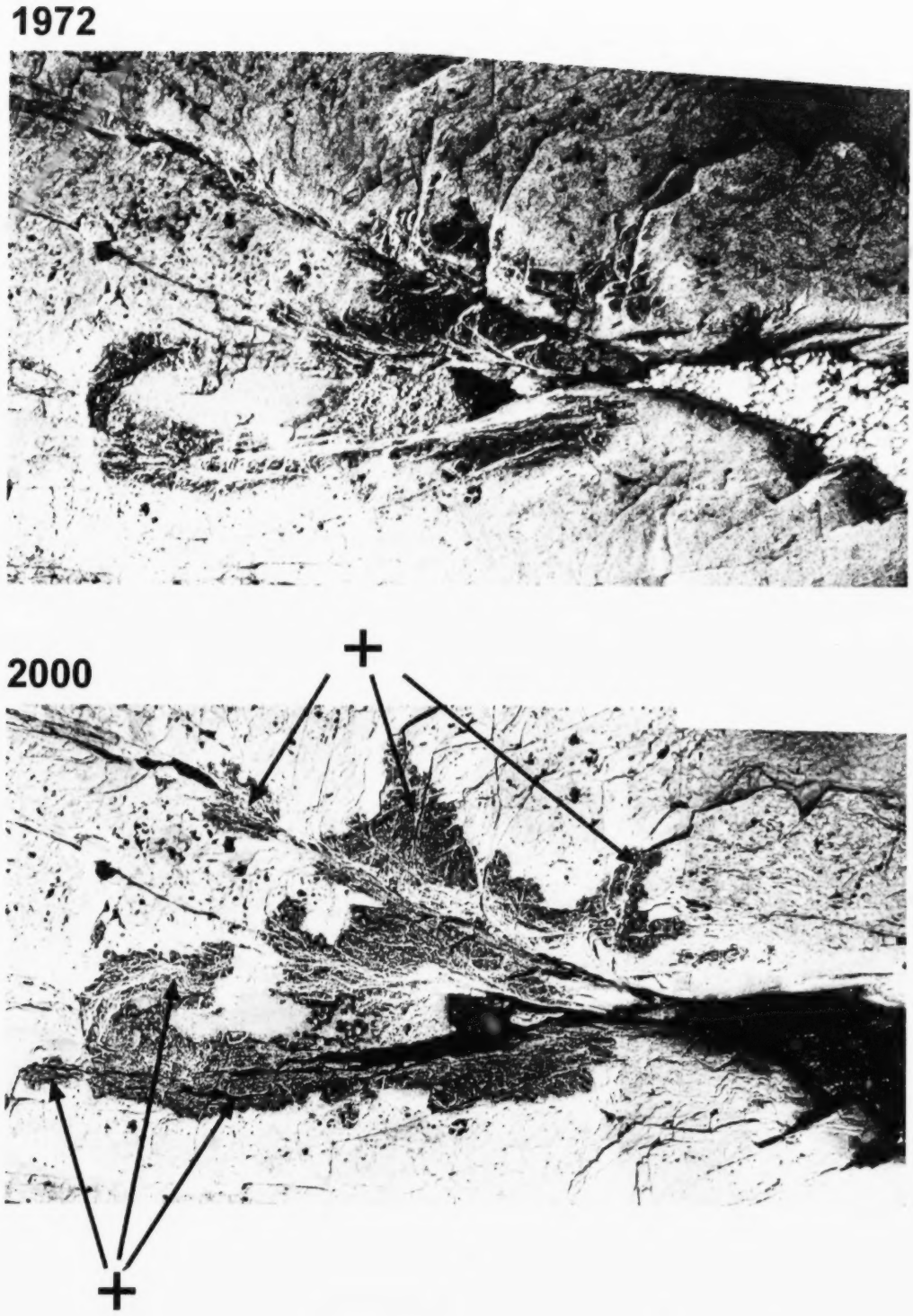

Figure 6. The Indian Gulch subcolony as it appeared on 19 June 1972 and 15 July 2000. Areas where murres have increased (+) and decreased (-) are indicated.

Table 2. Estimates (and 95% confidence intervals) of colony area and colony size (pairs) on Funk Island, Newfoundland in 1972 and 2000. The number of nesting pairs was calculated by multiplying the colony area estimates by estimates of the density of breeding pairs provided by Birkhead and Nettleship (1980). These were as follows: Southwest: 23.5 pairs/m^2, Central: 25.3 pairs/m^2, Indian Gulch: 20.0 pairs/m^2.

	Year	Southwest	Central	Indian Gulch	Total
Area of colony (m^2)	1972[1]	6,483	6,187	4,379	17,049
	1972	6,640	5,616	4,548	16,805
		(5,034 - 8,246)	(4,254 - 6,979)	(3,445 - 5,651)	(14,427 - 19,182)
	2000	6,023	6,195	5,713	17,931
		(5,025 - 7,021)	(5,196 - 7,194)	(4,790- 6,635)	(16,244 - 19,617)
Colony size (pairs)	1972[1]	152,350	156,531	87,580	396,461
	1972	156,046	142,091	90,960	389,097
		(118,310 - 193,781)	(107,624 - 176,558)	(68,905 - 113,015)	(372,857 - 405,337)
	2000	141,541	156,734	114,250	412,524
		(118,099 - 164,982)	(131,460 - 182,007)	(95,801 - 132,699)	(373,427 - 451,621)
% change[2]		-9	+10	+26	+6

1. Estimates from Birkhead and Nettleship (1980) shown for comparison; they did not provide estimates of variance.

2. Percent change in colony area and colony size between our 1972 and 2000 estimates.

determined from each feature varied and so a compromise scale was calculated by taking a mean. Most of the variation in the final colony size estimate was the result of the variance about this mean, and therefore, tighter confidence limits around the colony size estimate rely on more precise estimates of scale.

Photograph scale can be assessed from altitude and camera focal length, and from ground-truthed objects of known distances apart or positions. It is recommended that for future surveys the position of objects on Funk Island that are easy to identify from aerial photographs be determined as accurately as possible using GPS (modern GPS units with differential or WAAS [Wide Area Augmentation System] correction give position to 3 meters or less) or by modern surveying techniques. This could be done after all birds have left the colony (approximately mid- Novemeber) This would allow photographs to be "rubber-sheeted" using locations with a known position as control points so that the scale is consistent over the whole photograph.

Delimiting areas occupied by breeding murres on the photographs is another potential source of error and bias. Discriminating between murres and other dark objects (e.g. pools of water) can be difficult if the photograph is poor quality. Imagery from 1972 and 2000 was good quality and this was not an important factor: pools of water lacked the speckled texture of murre breeding areas and the colony could be easily delineated from the less-densely packed birds around the outskirts of the colony. Different workers may delimit colonies differently, introducing biases when comparing the results of two surveys. In this study, the original 1972 tracings were checked by one of us (JWC) and found to be in agreement with the standards used to trace the 2000 photographs. There is also error in the actual measurement of area occupied, however, our repeated measurements of colony areas with the planimeter were very close and thus do not represent a serious source of error.

The 1972 and 2000 surveys used very similar methodology with the exception that their timing differed by about 1 month (19 June 1972 vs. 15 July 2000). We do not think that this influenced the comparison for the following reasons: 1) murre adults and chicks start to leave Funk Island in the latter part of July (Tuck 1961, W.A. Montevecchi pers. comm.) so both surveys occurred before chick fledging commenced, and 2) the number of murres at the colony tends to remain fairly constant until chick fledging (Hatch and Hatch 1989).

A potential source of bias is in the colony area estimates is slope. Any slope would result in the areas measured on the photographs underestimating true area. We do not have quantitative slope estimates for the colony with which we could correct the area estimates. Anecdotal information provided by W.A. Montevecchi in 2000 indicated that some of the Indian Gulch subcolony is on a slope of about 20° from level, whereas, most of the Central subcolony is on flattish ground. Thus the Indian Gulch estimates of colony area and colony size are likely underestimates. However, as the subcolonies are more or less in the same positions in the two years of study, this bias would have affected both estimates equally and thus would not have confounded the inter-year comparison.

The density of murre pairs used to extrapolate to the total breeding population is another potential source of error and bias..In this study we used values presented in Birkhead and Nettleship (1980). They obtained their estimates by counting eggs and chicks in 10, 2 x 3 metre quadrats. This involved driving the birds from their eggs or chicks. We were not able to obtain our own estimates of density because it is not now permitted to land on Funk Island at a time when egg/chick counts would be possible, or to enter the murre colony during the breeding season. Thus, for the comparison between colony size estimates in 1972 and 2000 to be meaningful, we assume that breeding density has not changed. In the future, we plan to obtain photographic images in which individual murres are distinguishable, thus allowing estimates of breeding density and its variance. This variance could be incorporated into the error in the final population size estimate.

Although the distribution of murres breeding on Funk Island has changed somewhat between 1972 and 2000, the subcolony structure and the overall numbers have remained similar. In the Southwest subcolony, the expansion of the Northern Gannet colony has resulted in a decline of murres breeding around its perimeter. It is reasonable to suggest that these murres have been displaced to other parts of the island, most likely to the southern portions of the Southwest subcolony, which expanded between 1972 to 2000. In historical times, gannets also displaced Common Murres from the top of Bird Rock, Cape St. Mary's (Tuck, 1953).

Several workers have published estimates of the number of Common Murre pairs breeding on Funk Island prior to 1972. These data are summarised in Tuck (1961), Kirkham and Montevecchi (1982) and Montevecchi and Tuck (1987). Although methodology and observers changed across years (and the former remains largely undefined), the data provide a valuable impression of what has happened to the Common Murre colony on Funk Island over the last 70 years. Early estimates (1934-1945) ranged from 10,000 to 15,000 pairs, then, starting in 1951, Tuck provided six estimates ranging from 40,000 pairs in 1951 to a astonishing 500,000 pairs just eight years later. It is impossible to say how accurate Tuck's estimates were, but it is perhaps telling that in his 1953 report, which was the precursor to the classic book "The Murres", he does not quote his 1951, 1952 or 1953 figures for Funk Island, but instead quotes a 1945 estimate by Peters. What is clear from Tuck's early work on Funk Island is that the Common Murre colony grew significantly in the 1950s, and if the 1958 (400,000) and 1959 (500,000) figures are taken as accurate, to levels comparable to those found by us in 1972 and 2000.

The similarity of the 1972 and 2000 estimates, and the possibility that the colony has remained relatively stable since the late 1950s, may be evidence that colony size is being regulated in a density-dependent manner. In contrast, several other Common Murre colonies in eastern Canada increased over the same time period (e.g., Quebec North Shore colonies [Gilles Chapdelaine pers. comm.], and Witless Bay colonies [Greg Robertson pers. comm.]. Two candidate controlling factors at Funk Island may be nesting space and food availability. There does not appear to be a shortage of nesting space on Funk Island, which is about 18 hectares (180,000 m^2) in area, of which only about 10% is currently occupied by murres. However, much of this unused space may not be suitable either because it is occupied by gannets or puffins, covered in standing water, or too close to the shore and therefore subject to wave-wash in storms, particularly from the north and northeast. Avoidance of wave-wash may explain why murres nesting at the north end of the gannet colony in 1972 did not simply move further north as the gannets expanded in later years. It is conceivable that most of the habitat considered suitable by murres is currently being used, and further major expansion is not possible. If habitat is limiting on Funk Island, the colony may be producing an excess of recruits, which might explain the expansion of murre colonies elsewhere in eastern Canada.

Food availability may also limit colony growth. The main food of Funk Island Common Murres is capelin (*Mallotus villosus*), taken within a limited range of the breeding colony (Davoran and Montevecchi 2002). The Funk Island colony is so large that murres may be capable of depleting capelin within foraging areas over the course of an individual breeding season. This may negatively feedback on breeding success and adult survival and limit the ability of the population to grow beyond a certain point.

It is interesting to note that major changes have occurred in the marine ecosystem off the east coast of Newfoundland between the 1972 and 2000 censuses. A large offshore capelin fishery has come and gone in the 1970s (Brown and Nettleship 1984), the northern cod stock collapsed in the early 1990s (Mann and Drinkwater 1994), capelin are smaller and spawn later and less frequently on Newfoundland beaches (Carscadden et al. 2002), and in the early 1990s the region experienced a significant decline in sea-surface temperatures as a result of the North Atlantic Oscillation (Mann and Drinkwater 1994). Despite these changes, murre numbers have not been affected on Funk Island. It is possible that despite the changes, food availability for murres did not change, or

changes occurred, but the birds have been able to adjust their effort and maintain breeding success (see Uttley et al. 1994), although this may impact adult survival. Changes favourable to murres also have occurred between 1972 and 2000: the Newfoundland murre hunt (of which about 5% or 40,000 birds per annum prior to 1993 were Common Murres; Chardine et al. 1999), has been reduced to less than half through regulations implemented in 1993. Furthermore, murre mortality due to incidental entrapment in cod gill nets (see Piatt and Nettleship 1987) likely declined after the northern cod fishing moratorium commenced in 1992.

In conclusion, the Common Murre colony on Funk Island now numbers about 412,000 pairs and has not changed appreciably since 1972, although distributional shifts within the island have occurred. Funk Island is an important seabird colony at the regional, national and international levels and we strongly recommend that regular aerial surveys be conducted in the future to monitor this important colony of Common Murres.

Acknowledgments

We thank the Province of Newfoundland and Labrador, Department of Tourism, Culture and Recreation, for providing a permit to fly over Funk Island in 2000.

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